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GAMBIT DATABASE & EXPLORER

For analysis of real-time IRI Maps of foF2 and hmF2

14th International Ionospheric Effects Symposium

Alexandria • Virginia • May 12, 2015

Session 1a | Ionospheric & Space Weather Models



Outline

- **Assimilation Techniques for IRI [model of Ne]**
 - **1. GIRO:** source of real-time ionogram-derived data
 - **2. IRI** empirical model formalism
 - **3. NECTAR** assimilative “model morphing” technique
 - **= IRTAM:** real-time global nowcasting
 - 4D Data Assimilation (**4DDA**): 24 hour context
 - **foF2** and **hmF2** maps vs TEC maps
- **GAMBIT Database and Explorer**
 - Public access to IRTAM results and analysis tools
 - Open source (2015)
- **Outlook: where do we go from here?**
 - IRTAM versus physics-based assimilative modeling
 - Spatial prediction capability: covariances?
 - Time forecast capability

1. Global Ionosphere Radio Observatory

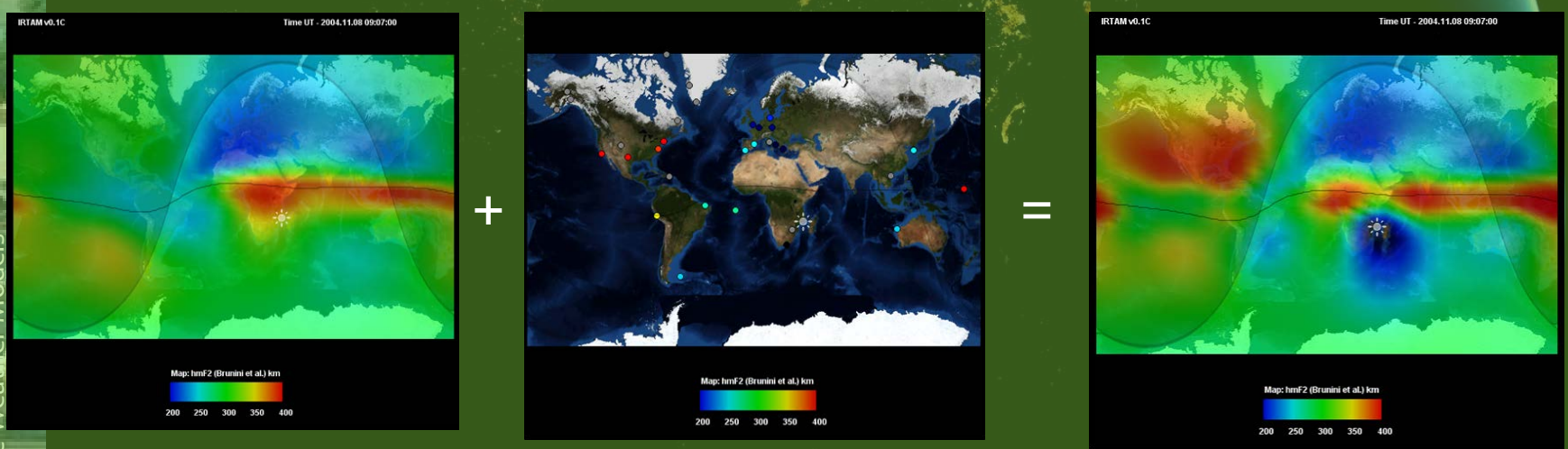
Real-time GIRO ionosondes, ~50 locations



IRI Real-Time Extension



Height of maximum F2 Layer Ionization (hmF2)

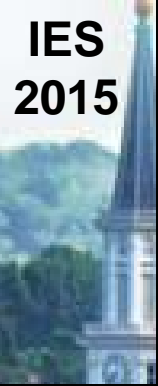


Global hmF2 "Climatology" IRI

Ionosonde Network Real-Time hmF2

Global hmF2 Weather

- Credits to the Real-Time IRI Task Force (2009)



IRTAM 24-hour History

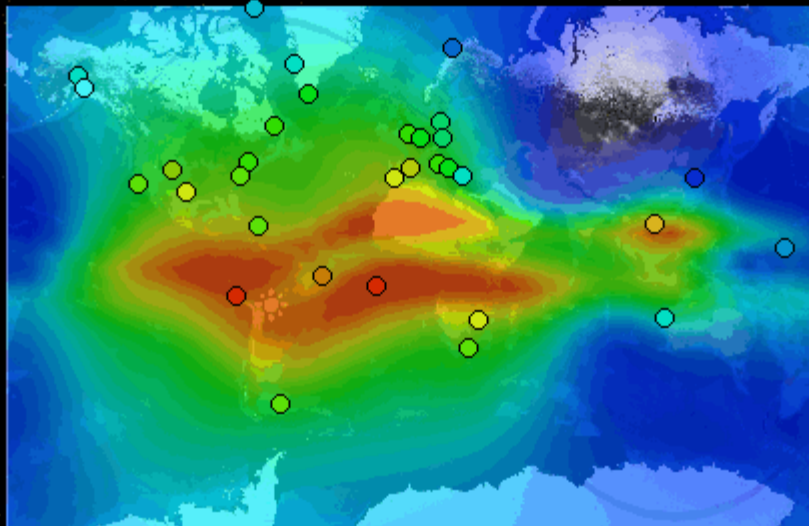


0.1C

Time UT - 2004.11.07 15:52:00

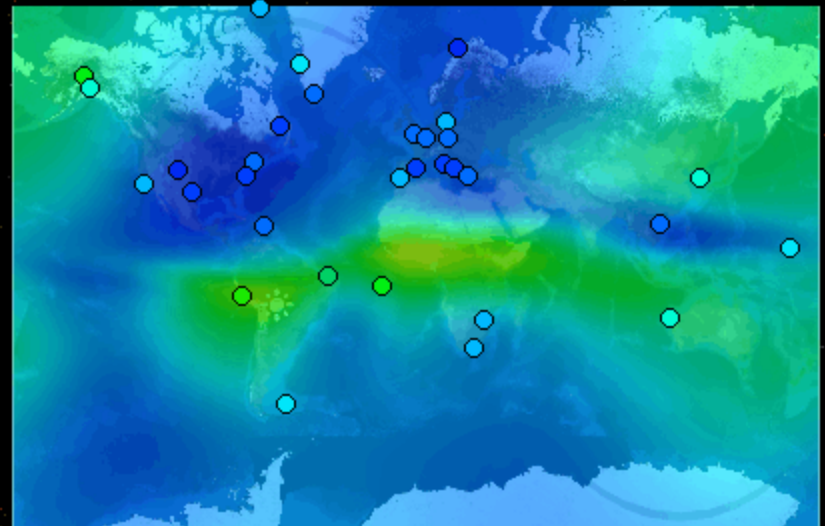
IRTAM v0.1C

Time UT - 2004.11.07 15:52:00



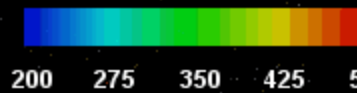
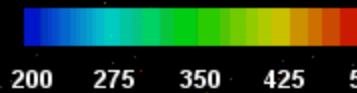
Map: foF2 (IRTAM) MHz

Sites: foF2 (GIRO) MHz



Map: hmF2 (IRTAM) km

Sites: hmF2 (GIRO) km



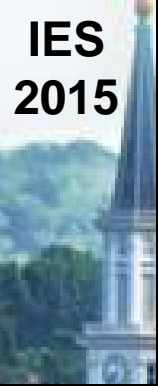
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f_0F2



h_mF2





IES
2015

IRTAM Deviation Maps

HOW IONOSPHERE IS DIFFERENT FROM ITS QUIET-TIME STATE



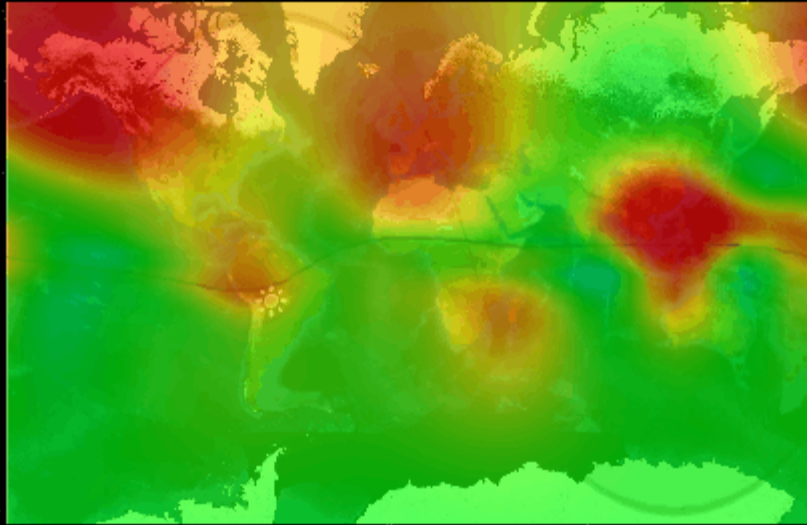
Global
Nowcasting

0.1C

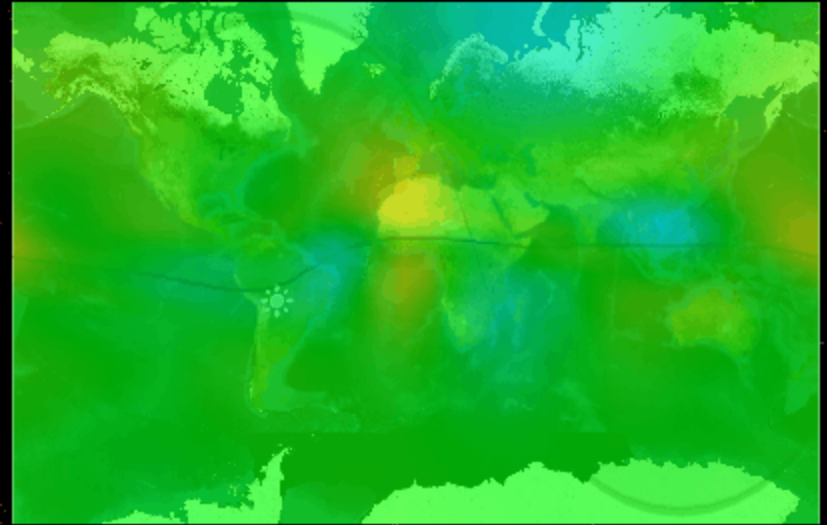
Time UT - 2004.11.07 15:52:00

IRTAM v0.1C

Time UT - 2004.11.07 15:52:00



Map: foF2 (IRTAM-IRI) MHz



Map: hmF2 (IRTAM-Brunini) km



$$\Delta f_0 F2$$

Is this real?

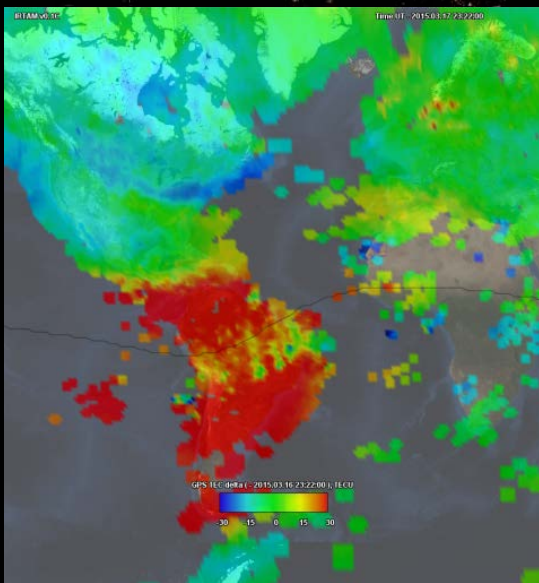
$$\Delta h_m F2$$

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IRTAM complementary to TEC maps

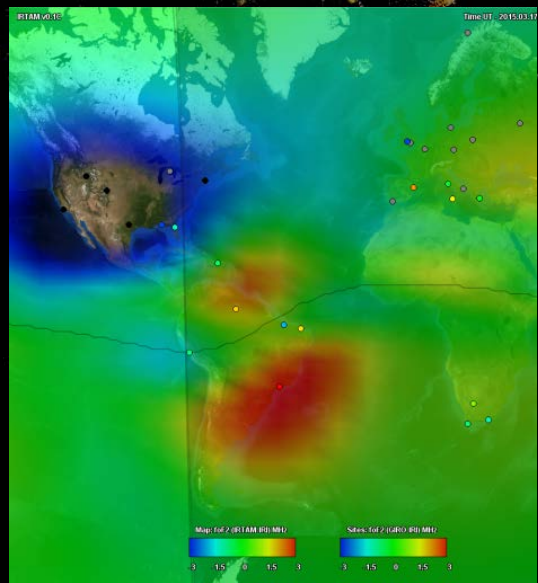
Substorm March 17, 2015 23:22UT

Δ TEC



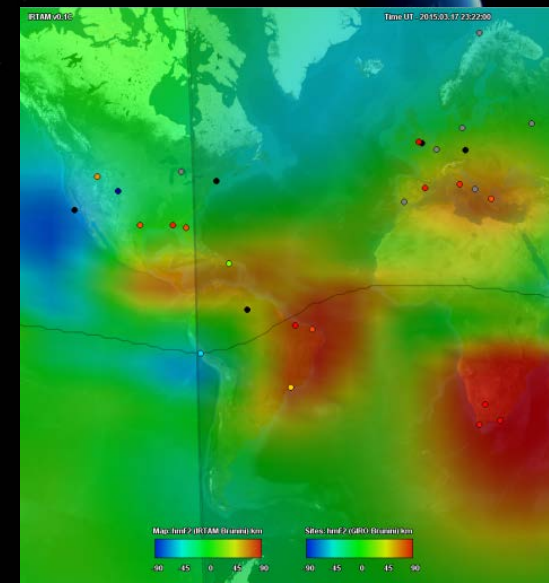
100s sensors
(no interpolation)

Δf_oF2



10s sensors

Δh_mF2



TEC maps courtesy Madrigal Node at MIT Haystack Observatory; [Coster et al., 2008]

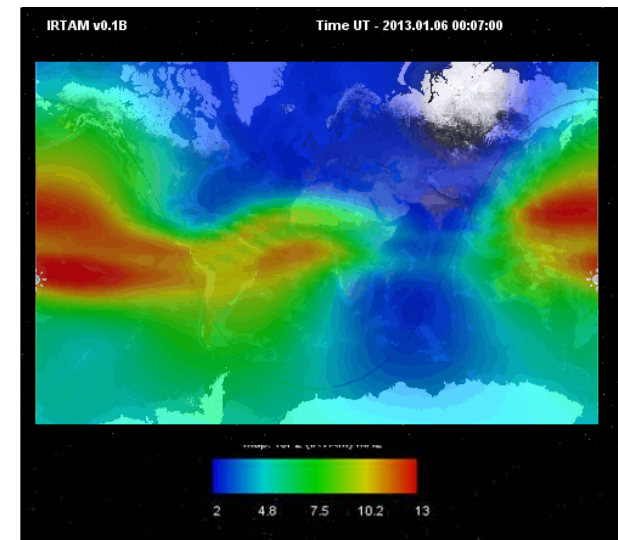
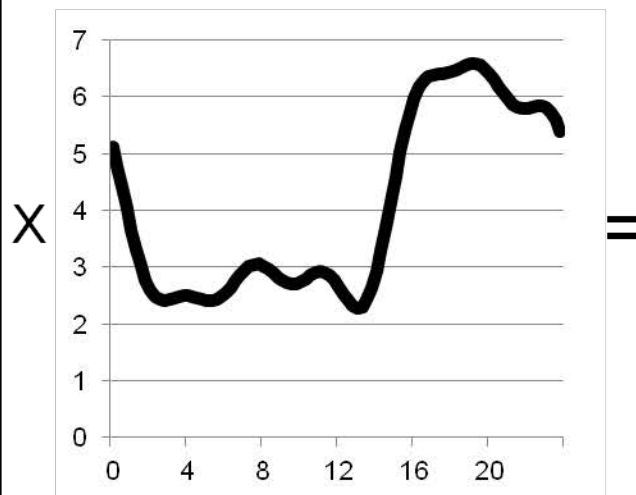
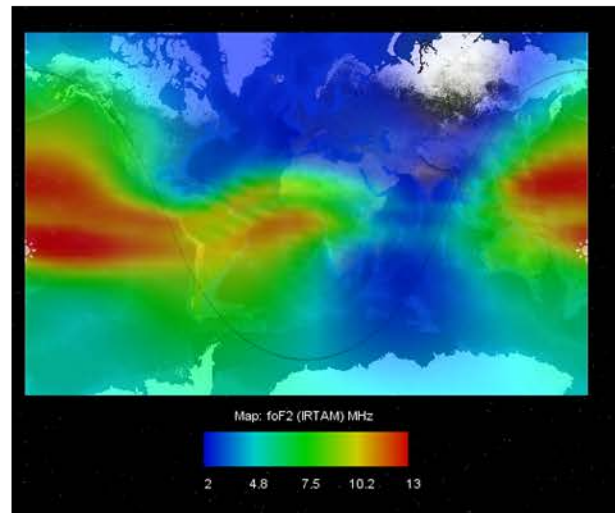
Under the Hood: IRI Formalism

988 coefficients

Spatial 76 coefficients subset:
Global 2D specification for a given **time**

Temporal 13 coefficients subset:
24-hour specification for a given **location**

Total 988 coefficients set:
Global 2D, 24-hour map



Assimilation Technique



- **NECTAR: Non-linear Error Compensating Technique for Associative Restoration**
- **Keep IRI expansion basis unchanged**
 - **Jones-Gallet geographic functions G_k – 76 functions**
 - **6th order of diurnal harmonic analysis – 13 functions**
- **Compute new coefficients C_{ij} that minimize data-model error**
- **Disseminate new 988 coefficients to existing IRI users**
 - **Small, efficient, no changes to the IRI engine necessary**

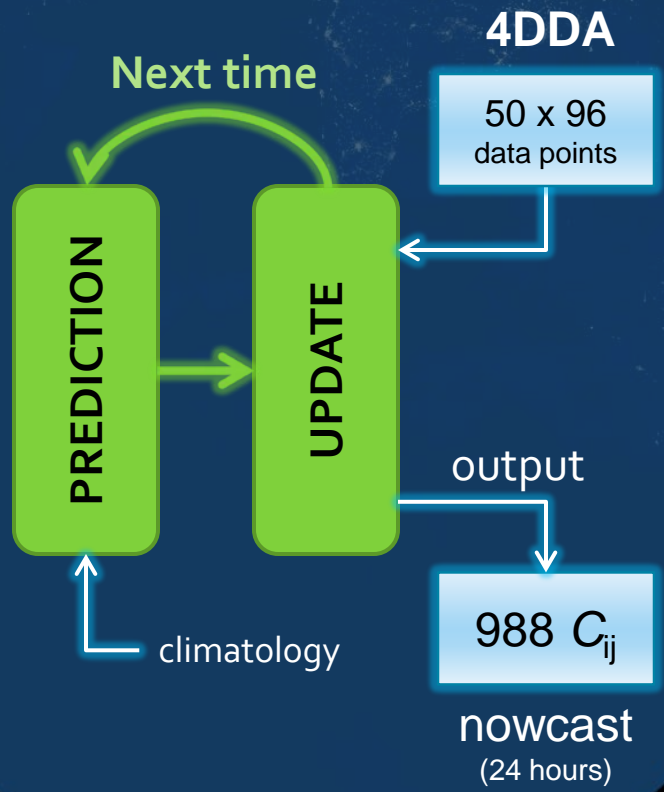
4D Data Assimilation (4DDA)

- **One nowcasting calculation = match of 24-hour history of data with 24-hour model = 24-hour 4DDA scheme**
 - **Overdetermined in time (96 times, 13 coefficients)**
 - **Underdetermined in space (40 observatories, 76 coefficients)**
 - **Not a classic Kalman filter mated to a first-principles model...**
 - **Ionosphere in terms of its “Eigen functions” describing the essence of its timeline behavior**

Empirical vs Physics-Based Assimilation

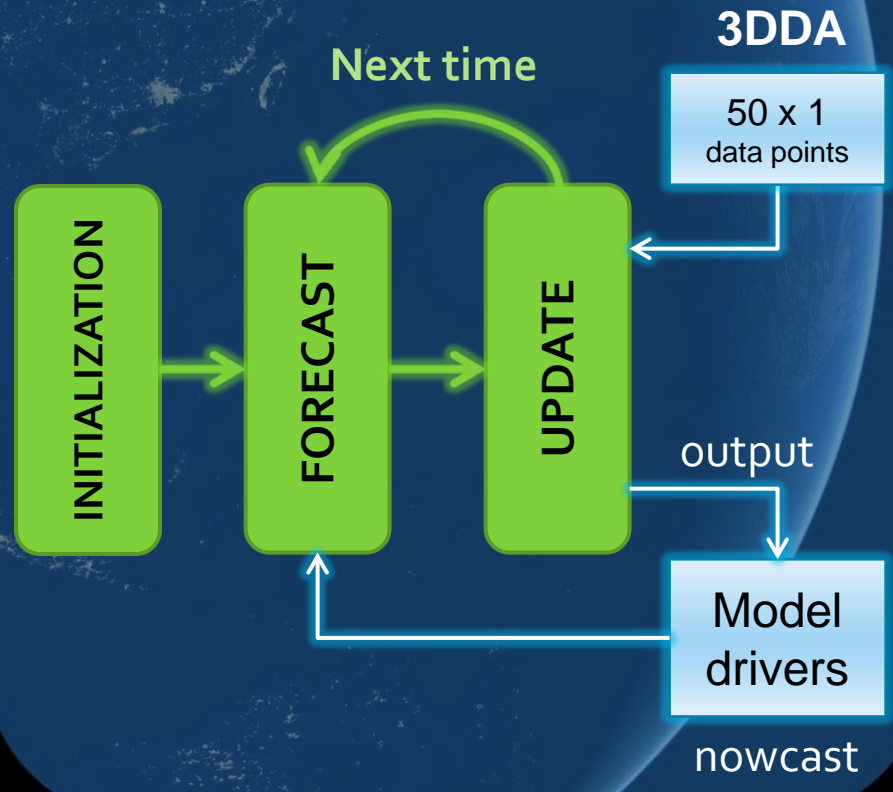
COMPLEMENTARY TECHNIQUES

EMPIRICAL



Represents processes yet to be understood

PHYSICS-BASED

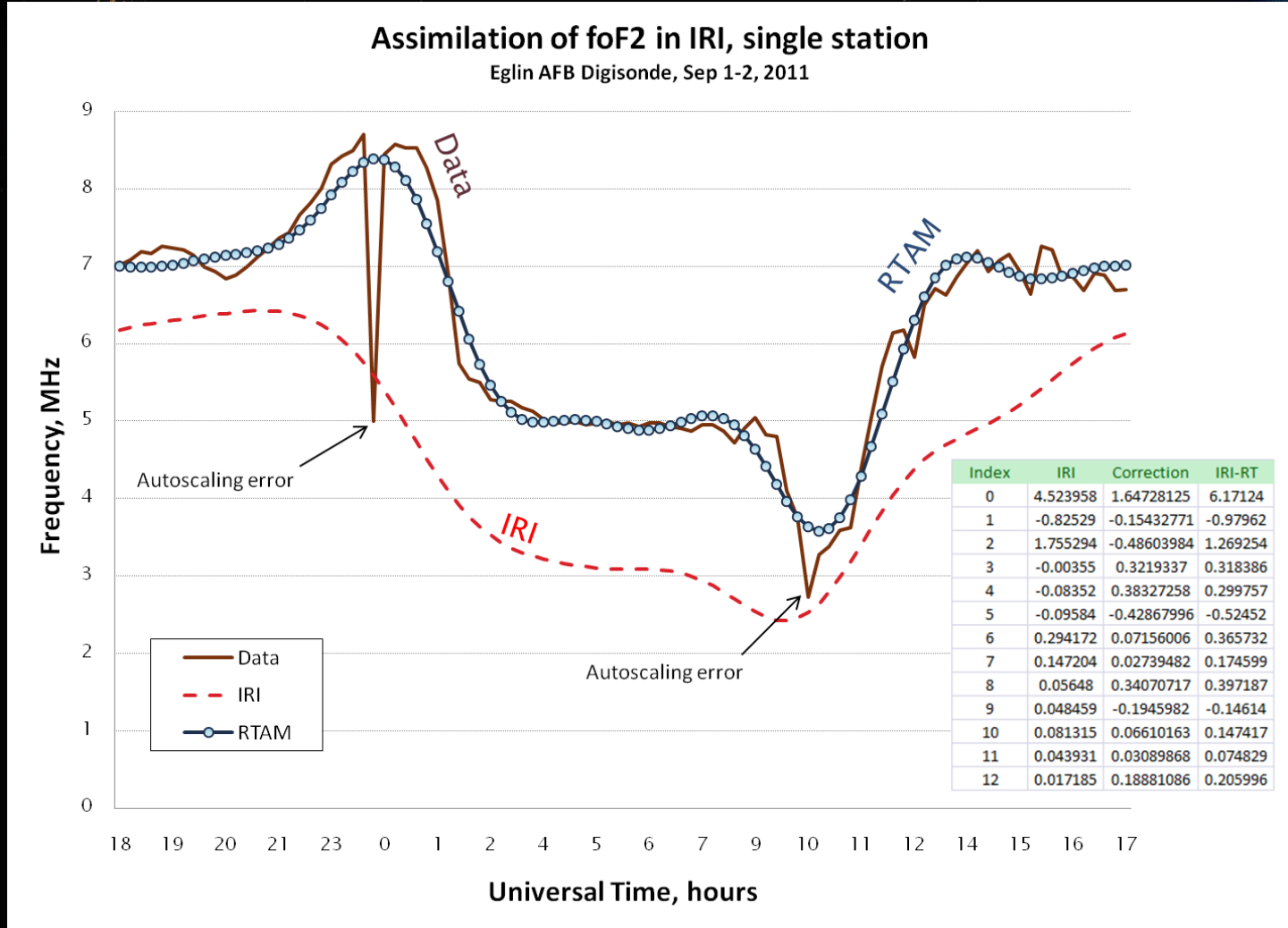


Describes system in terms of constituent processes

24-hour Temporal Harmonics Expansion

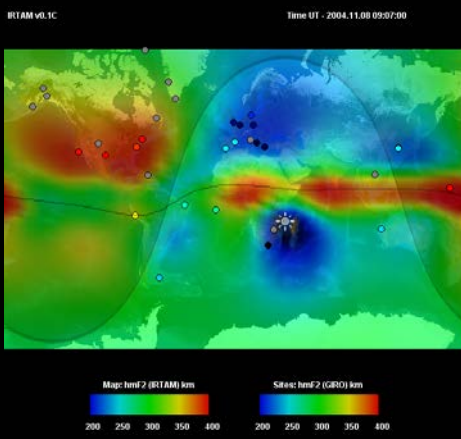
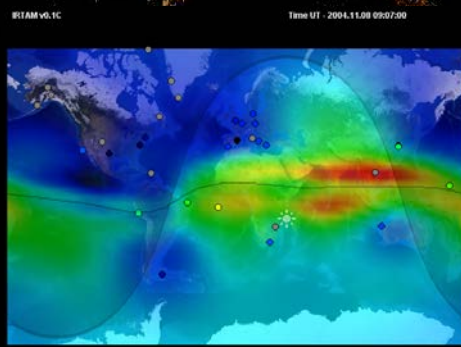
4DDA approach is robust to autoscaling blunders

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Eglin AFB foF2 series courtesy AFWA NEXION program

Near Future: Global Realistic Ionosphere using GIRO Real-time Data Feeds



foF2

hmF2



Background 3D



TID modulation

To raytracing



GAMBIT Database and Explorer

<http://giro.uml.edu/GAMBIT>

GAMBIT Homepage

giro.uml.edu/GAMBIT/

Apps Test port 3050 Net-TIDE Solar Physics Glossary Ontology editor Index of /ftplib/lists... https://www.gsj.jp/i... LiebertRoom at Go...

UMASS LOWELL

GAMBIT
GLOBAL
ASSIMILATIVE
MODEL OF
BOTTOMSIDE
IONOSPHERIC
TIMELINES

Map: hmF2 (IRTAM-Brunini) km
Sites: hmF2 (GIRO-Brunini) km

Gambit

Early release [User Version 0.1C download](#) (64-bit Java 7 or higher is required)
Early release [GAMBIT Explorer User Guide 0.1C](#)

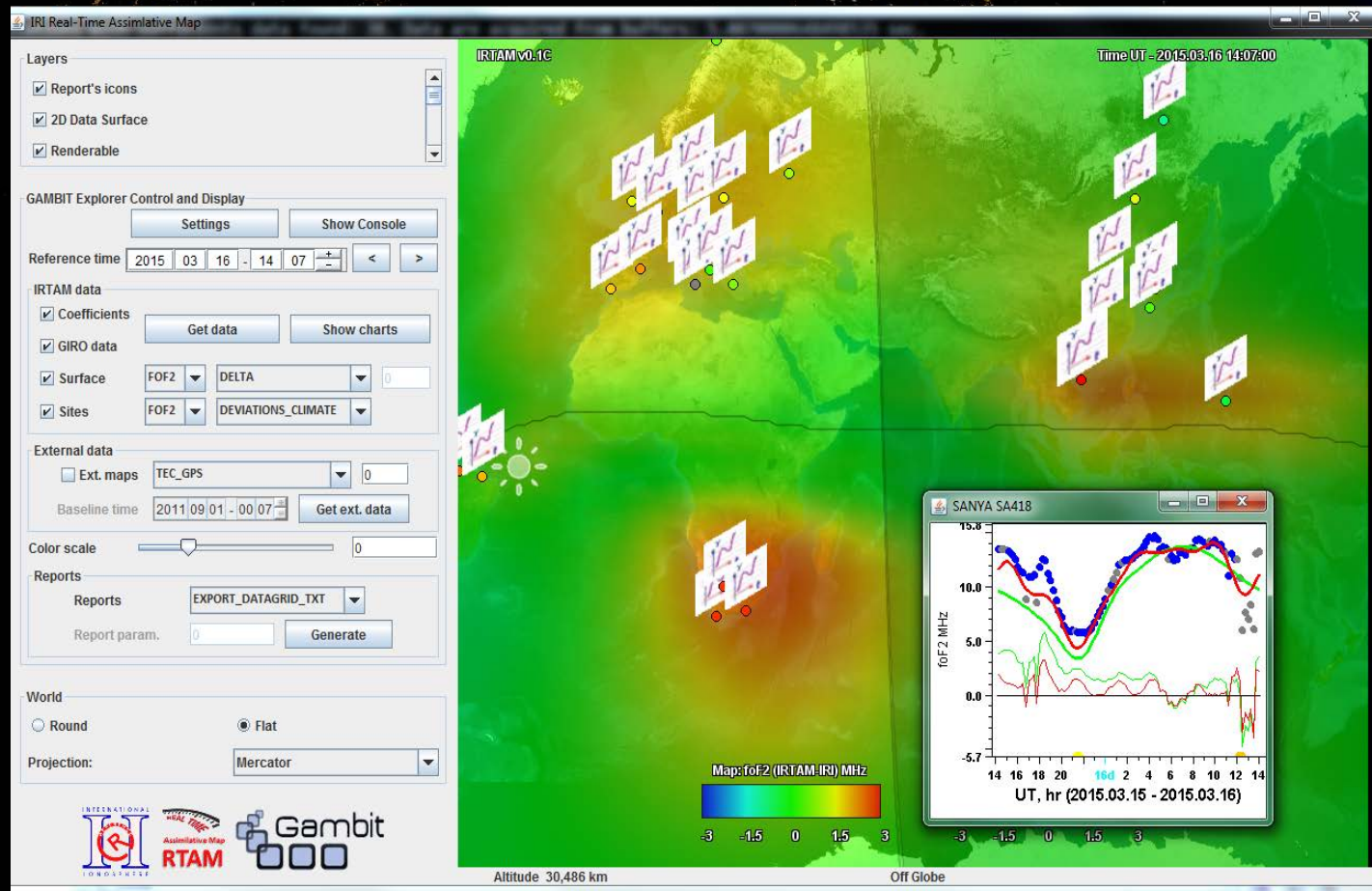
**IRTAM foF2 and hmF2 timelines since 2000
+ real-time data with 10 min delay**

Last updated: April 16, 2015

Public access to IRTAM retrospective and current results

GAMBIT Explorer

Global Assimilative Model for Bottomside Ionospheric Timelines



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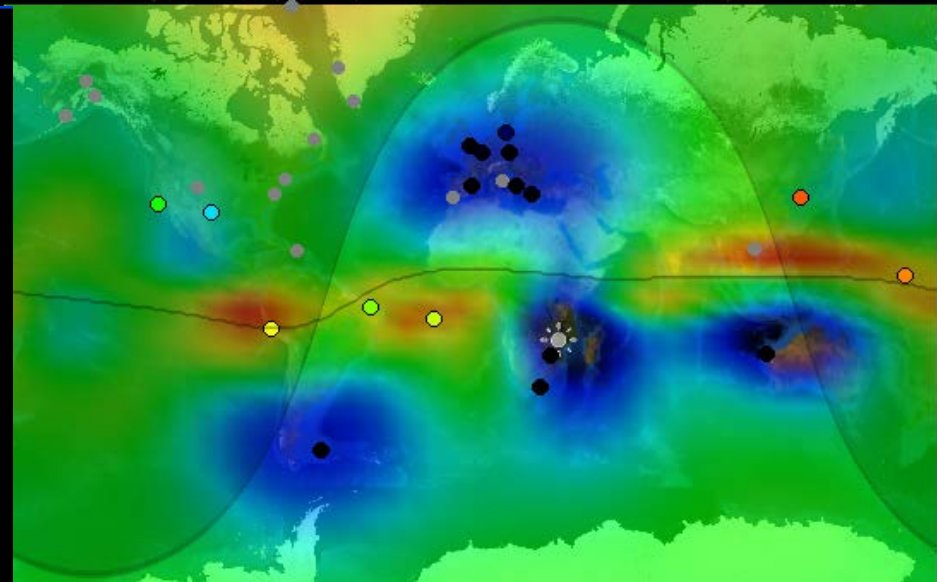
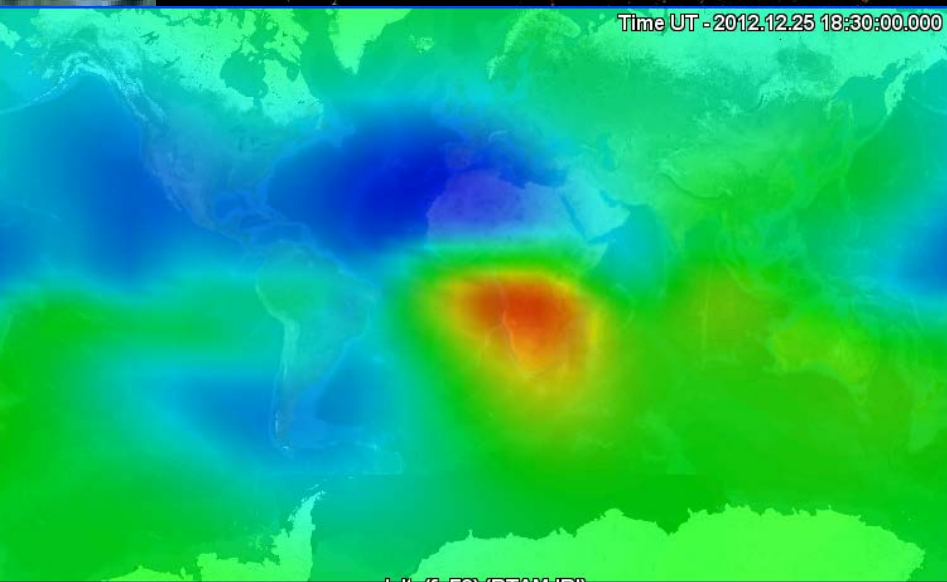
Future work: Covariance study

Δf_oF2

Δf_oF2

IRTAM v0.1B

Time UT - 2004.11.08 09:30:00



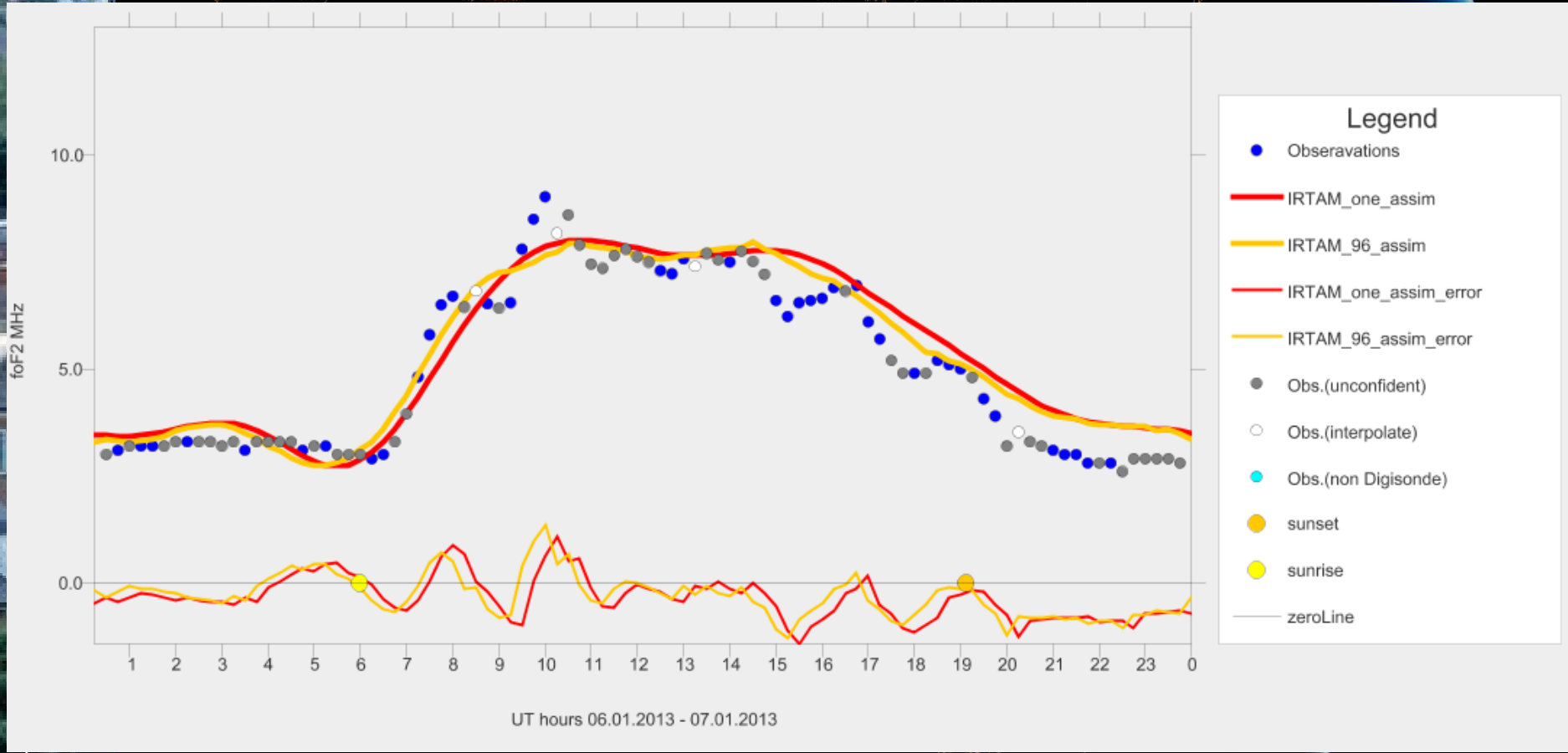
5000 Km

Slow attenuation
(large covariance)

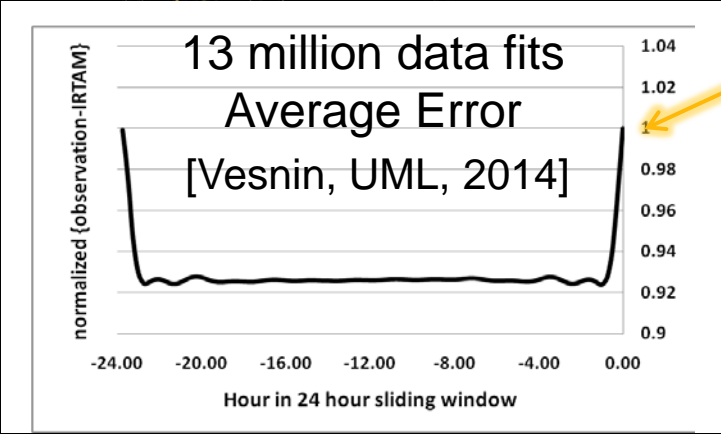
VS.

Fast attenuation
(small covariance)

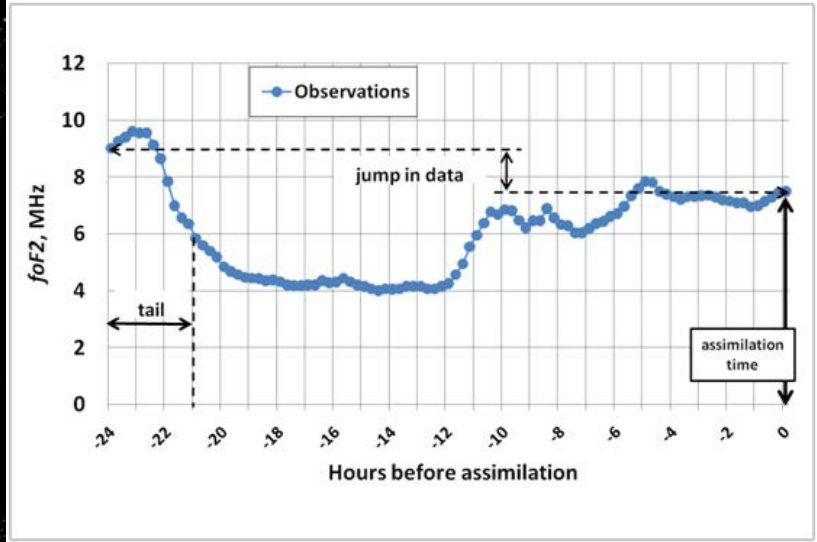
IRTAM resolution = IRI resolution?



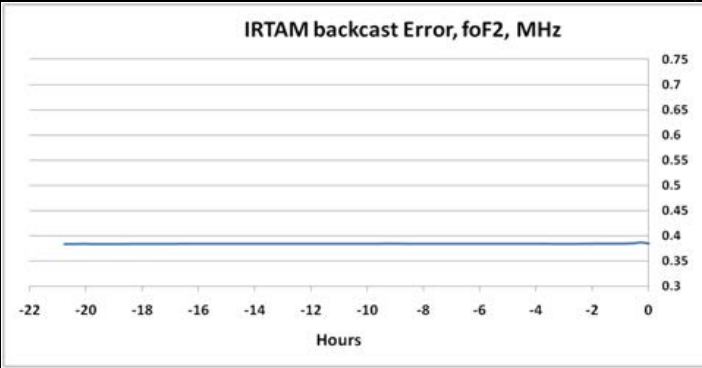
Managing the Day Boundary Issue



Inertia of the model?

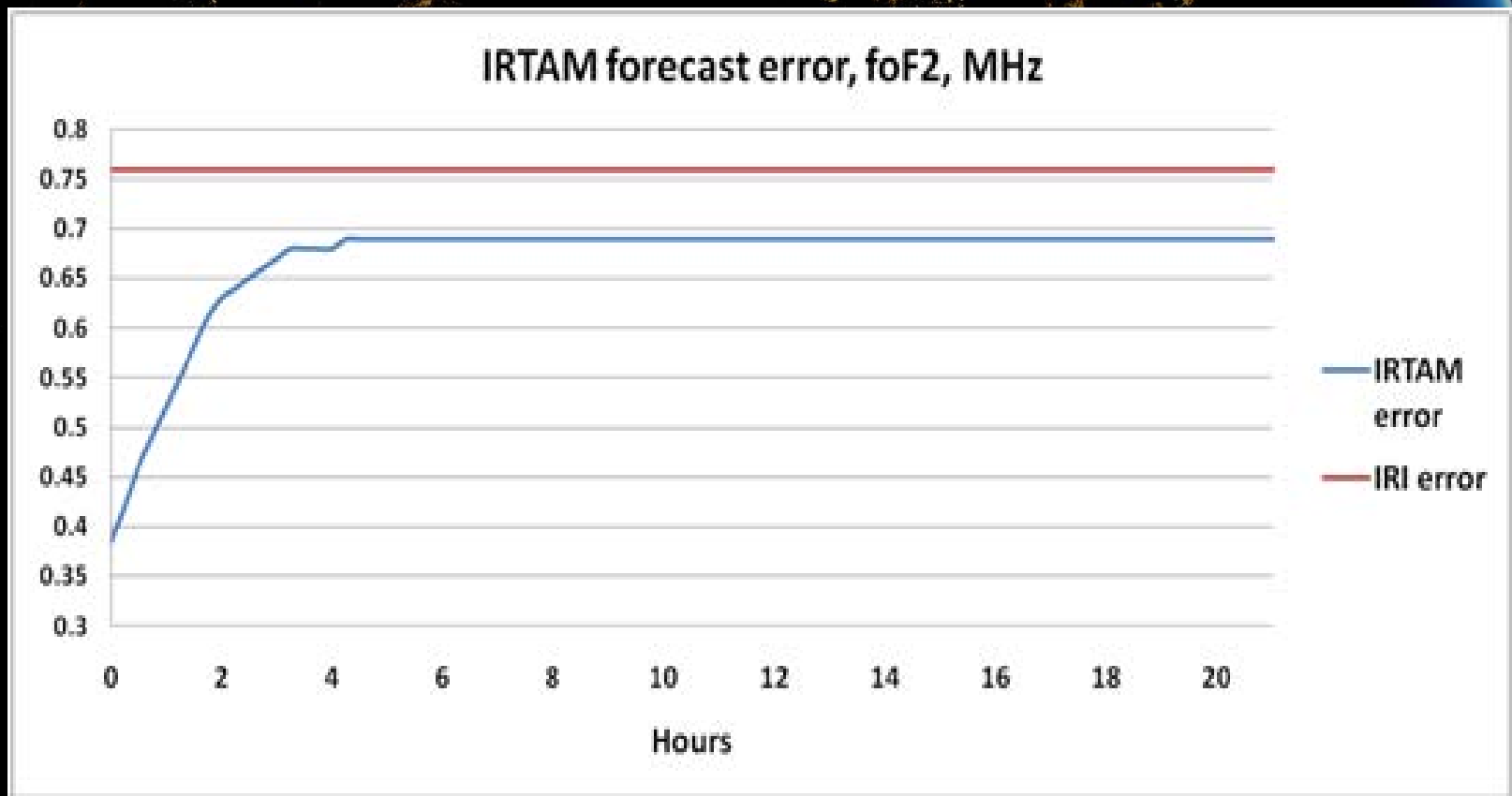


Average error of IRTAM matching source data



SOLUTION: 24-hour expansion using 21 hours of data

IRTAM in Forecast Mode



Outlook

- **URSI INAG Working Group G.1 actively pursues real-time ionosonde network operation**
- **IRI-based Real-Time Assimilative Model is in operation since January 2013; IRTAM validation in progress**
- **RETID (USA) and Net-TIDE (Europe) projects support TID detection and evaluation using Digisonde data**
- **Lowell GIRO Data Center builds a public, open-source environment for realistic ionosphere nowcast based on ionosonde data feeds**
- **Cooperations with CEDAR Madrigal, NASA CCMC and VWO, European ESPAS are good opportunities to provide **single-stop data dissemination portals** for realistic ionosphere nowcast**

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